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Air Force Domestic Technology Transfer: Is It Effective?

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COLONEL A. MICHAEL HIGGINS

ABSTRACT

This paper first defines domestic technology transfer and explains that this transfer of technology from government laboratories to defense industries is key to the U.S.'s national security strategy of "Maintaining the Technology Edge" to ensure military superiority. The paper then provides examples of U.S. Air Force technology transfer that demonstrate that this transfer has not only resulted in military superiority but it has also been a crucial part of America's economic leadership and strength in some commercial markets. The rising importance of this technology transfer from government laboratories to the commercial sector is examined and a survey of recent technology transfer laws is presented. The U.S. Air Force response to these new laws is then covered. Finally, some current issues in domestic technology transfer are discussed.

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U.S. AIR FORCE DOMESTIC TECHNOLOGY TRANSFER:

IS IT EFFECTIVE?

INTRODUCTION

As one considers the topic of technology transfer, a number of questions probably come to mind. For example, who in the Air Force is transferring the technology and who is receiving it? What constitutes technology transfer? Is this transfer important? How is the effectiveness of this transfer measured?

Each of these questions is valid and they point out the necessity of establishing common ground for the discussion to follow. Thus, let us begin this paper with the development of this common ground. First, for this paper, I will use the definition of technology transfer that is given in AFR 80-27[1] :

> oral or written information or data; hardware; personnel, services, facilities, equipment; or other resources relating to scientific or technological developments of a U.S. Government Research, Development, Test and Engineering (RDT&E) activity, provided or disclosed by any means to another federal agency; a state or local government; an industrial organization, including cooperation, partnership, limited partnership, or industrial development organization; public or private foundation; nonprofit organization, including a university; or other person to enhance or promote technological or industrial innovation for a commercial or public purpose.

Since the subject is limited to the Air Force, the definition of technology transfer will, in most cases, be limited to only the technologies transferred from the Air Force. And since technologies are primarily developed in the Air Force Laboratory system, in this paper the

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[1] AF Regulation 80-27, Research and Development, Domestic Technology Transfer, Department of the Air Force, Headquarters US Air Force, Washington DC, 31 Jan 1990.

definition will be further limited, in general, to the Air Force laboratories as the transferring agency. Therefore, the definition can be restated as "something of technological value transferred by the Air Force Laboratories to some entity." Since technology transfer can be made by mistake to either potential military enemies or economic competitors, the term domestic technology transfer is used to specify that transfer that ends up in the domestic arena. In this context, domestic arena means American companies as opposed to foreign "transplants" on American soil. Within the U.S. Federal Government, the Department of Defense (DoD), and the U.S. Air Force (USAF), this type of technology transfer is referred to as Domestic Technology Transfer or DT2[2] because the transfer is to a domestic (U.S. owned) entity. In summary then, this paper is really concerned with the transfer of "something of technological value" that is transferred by the Air Force Laboratories to some domestic entity, i.e., USAF domestic technology transfer.

It should also be noted that other terms are sometimes used to describe technology transfer. One of these is technology diffusion and this is really an equivalent term. Because both of these terms, technology transfer and diffusion, are somewhat passive, that is, it says nothing of whether the transfer is useful (i.e., whether the technology is used or employed), another term, "technology deployment", has been suggested[3]. In this paper, the more common term, "domestic technology transfer" will be used with the implication that the technology transferred or diffused

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[2] Hittle, Audie Eugene, "Technology Transfer Through Cooperative Research and Development." Master of Science Thesis, Massachusetts Institute of Technology, June 1991.

[3] Chatlynne, C.J., Program Manager of USAF Domestic Technology Transfer Program, Office of Assistant Secretary of the Air Force (Acquisition), Directorate for Science and Technology. Personal communication.

will be employed.

Why is technology transfer important? In defense, the U.S. has always depended on the "Technology Edge" to maintain a superior war-fighting capability over potential enemies who were expected in most cases to have a numerically superior force.[4] This strategy is reiterated each year by the Secretary of Defense in testimony before Congress.[5] Indeed, Assistant Secretary of the Air Force (Acquisition) Jack Welch was very clear in his 1991 statement to the Committee on The Armed Services' Subcommittee for Research and Development that "The Air Force has remained steadfast over the years in stressing the importance of quality in our systems, or "maintaining the Technology Edge" to counter the quantity of enemy weapon systems."[6] This strategy was very apparent during the Gulf War of 1991. The weapon systems of the U.S. forces, from surveillance satellites and communications systems, fighter aircraft, and precision guided munitions were technologically superior to those of the countries of the rest of the world. Much was made of the camera coverage of precision air strikes that showed the unbelievable accuracy of precision guided bombs as they almost effortlessly, it seemed, knocked out buildings in the center of Baghdad (with minimum damage collateral damage to surrounding structures), dropped bridge spans, and penetrated reinforced aircraft shelters. Although Iraq had obtained the latest

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4 U.S. Congress, Office of Technology Assessment, "The Defense Technology Base: Introduction and Overview -- A Special Report," OTA-ISC-374, Washington, DC, U.S. Government Printing Office, March 1988, p. 3.

5 Cheney, Dick, Testimony before the Senate Armed Services Committee, January 31, 1992, Witness statement, p.27. Secretary Cheney enumerated several reasons for "continuing our strong emphasis on maintaining our technological edge".

6 Welch, John J., Jr, Air Force Assistant Secretary (Acquisition) and Jaquish, John E., LtGen, USAF, (Principal Military Deputy Assistant Secretary (Acquisition), Statement to the Committee on Armed Services, Subcommittee on Research and Development, United States House of Representatives, March 1991, page 8.

versions of various weapons systems from other nations in the world (principally the Soviet Union) and had a roughly equivalent force size, the exchange ratio of casualties and captured was approximately one-thousand to one in favor of the Allies . As a result, the DoD strategy of "technological superiority" was validated convincingly.

Because of this "technological superiority" strategy, the Defense Department — and the Air Force — has stressed the importance of a vigorous, continuing technology development effort with timely technology transfer to the U.S. defense industries. Indeed, Air Power has always been closely linked to science and technology. As an Air Force historian stated:

> The very reality of flight depended upon a technical innovation. Unlike the other services, where machines merely support the mission, technology is for the Air Force at the very heart of its existence as an institution. As a consequence, the USAF and its predecessor organizations have always recognized the singular importance of science to their survival.[7]

Consequently, a robust DoD research and development (R&D) spending plan was maintained throughout the latter part of the twentieth century that invested up to two-thirds of the nation's Federal R&D funding[8] and nearly one-half of all the U.S.'s R&D funding[9]. For fiscal year 1989, the Defense R&D budget amounted to $42.2 billion. Science and Technology (S&T), the component of R&D that is directed toward the development of generic military technologies

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[7] Gorn, Michael H., *Harnessing the Genie: Science and Technology Forecasting for the Air Force 1944-1986.* Office of Air Force History, United States Air Force, Washington, DC, 1988, p. v.

[8] Berger, Suzanne, Dertouzos, Michael L., Lester, Richard K., Solow, Robert M., and Thurow, Lester C., "Toward a New Industrial America," *Scientific American*, June 1989, Vol. 260, No. 6, p. 42.

[9] National Science Board, *Science & Engineering Indicators -- 1989.* Washington, DC: U.S. Government Printing Office, 1989, p. 87. (NSB 89-1)

(i.e., not for a particular weapon system) and is typically done through the DoD laboratories, is about 10% of the R&D total. In 1989 the DoD laboratories were allocated $6.2 billion and that is approximately 30% of all S&T spending in the U.S.[10] Although Defense R&D is decreasing in the 1990s, S&T funding is expected to increase at a 2% real growth rate demonstrating the consensus that the U.S. must maintain the "technology edge" in military systems.

Thus, DoD has focused on developing new technologies and inserting them into defense systems such as advanced fighter jets or missiles. Advantages that accrued to industry were referred to as "spin-offs." Commercial development and application of new technologies have for the most part been considered the responsibility of the private sector.[11] Indeed, the U.S. Technology Policy issued by the Office of Science and Technology Policy specifically states that "the private sector has the principal role in identifying and utilizing technologies for commercial products and processes."[12] But as Admiral Bobby Inman, the first head of SEMATECH (the government-industry consortium for the development of semiconductor technologies) and a current member of the Executive Committee of the Council on Competitiveness, pointed out, "In the 1980s, as international competition eroded the once commanding U.S. advantage in technology, both industry and government began to rethink their traditional roles in the

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[10] 1990 Defense Science Board Summer Study on Technology and Technology Transfer Policy (Draft of Final Report), Office of the Under Secretary of Defense for Acquisition, The Pentagon, Washington, DC, August 1990, pp. 1, 2.

[11] Berger, Suzanne, Dertouzos, Michael L., Lester, Richard K., Solow, Robert M., and Thurow, Lester C., "Toward a New Industrial America," *Scientific American*, June 1989, Vol. 260, No. 6, p. 42.

[12] U.S. Technology Policy, Executive Office of the President, Office of Science and Technology Policy, Washington, DC, September 26, 1990, p. 3.

development and application of technology. The implications for foreign policy stem from one overriding fact: when it comes to advanced technology, national security can no longer be viewed in purely military terms; economic security is also a vital consideration.[13]" It became more and more clear to many that domestic technology transfer is essential for the United States to remain competitive in the global marketplace. With that goal in mind, the U. S. Congress passed a series of laws during the last decade to enhance technology transfer. A discussion of those initiatives are presented in the next section.

Congressman Ron Wyden provided insight into Congressional thinking in 1989 when he stated, "The most important single resource for new technologies may be the Federal laboratory system — a network of several hundred labs which spends more than sixty billion Federal tax dollars per year for both basic and applied research." Here, of course, the Congressman was talking about the total R&D budget of which the Federal Laboratories, including the USAF laboratories, are only a small part as noted earlier. On April 10, 1987, President Ronald Reagan stated in a presidential press release that:

> It is important not only to ensure that we maintain American preeminence in generating new knowledge and know-how in advanced technologies, but also that we encourage the swiftest possible transfer of Federal developed science and technology to the private sector. All of the provisions of (Executive order 12591) are designed to keep the United States on the leading edge of international competition.

Indeed, as Inman observed, it was not "a lack of advanced technology or a failure of research that led to the downfall of certain basic American industries, but the inability to bring

[13] Inman, B.R., and Burton, Daniel F., Jr, "Technology and Competitiveness: The New Policy Frontier," *Foreign Affairs*, Spring 1990, p. 116.

new technology rapidly to the marketplace and to manufacture high-quality products.[14]"

Thus, the metric for measurement of the effectiveness of DoD (and therefore Air Force) technology transfer seems to be changing to include the effectiveness of transfer of technology to domestic commercial industries as well as to defense industries. Prior to 1980, the measure of effectiveness would have been how well the Air Force Labs transferred technology to the U.S. defense industries for incorporation into weapon systems.

The next section of this paper will discuss how the Air Force laboratories approached this task and some of the successes. Next, we will examine the laws enacted by Congress to facilitate the transfer of technology from the USAF Labs to the commercial sector, the response of the Air Force Labs to these laws, and the problems and opportunities this new challenge presents. Finally, we will examine the future course of Air Force Domestic Technology Transfer.

TECHNOLOGY TRANSFER TO DEFENSE INDUSTRIES

As we have seen, the primary goal of the Air Force labs prior to at least 1980 was the transfer of technology to defense industries to "maintain the technology edge" of the U.S.'s warfighting systems. Any advantages to the commercial sector were really thought of "spin-offs" and were welcome as a useful by-product that partially justified the large defense expenditures and enhanced the industrial base.[15]

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[14] Ibid., p. 120.

[15] U.S. Congress, Office of Technology Assessment, "Holding the Edge: Maintaining the Defense Technology Base". OTA-ISC-420 (Washington DC: U.S. Government Printing Office, April 1989), p. 3.

How does the Air Force manage its laboratories to obtain an efficient development of technologies and a flow of these technologies into industry? To understand that we must first briefly look at the way the DoD allocates funding. Funding for technology development is provided in three categories as shown below:[16]

(1) Basic Research — budget category 6.1.

> The development of new ideas that are principally paper products backed up by experiments and theoretical calculations.

(2) Exploratory Development — budget category 6.2.

> Laboratory bench-top feasibility determinations are conducted on military technologies derived from the principles discovered in basic research.

(3) Advanced Technology Development — budget category 6.3 ATD.

> The testing of hardware in a "near" military environment to reduce risk of full scale development of the technology and to expedite domestic technology transition.

The sum of these three categories is the Science and Technology (S&T) program. It is important to note that S&T does not include Advanced Development Programs, budget category 6.3B. Advanced Development is system specific and is the first step in the acquisition process.

Thus, in basic research a fundamental idea or process is conceived and explored. As it matures, it moves into the exploratory development category for further definition and development. Then, if the exploratory development process is successful, a part (of course it might also be a process, skill, or technique) is constructed and tested as part of a generic system.

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[16] Welch, John J., Assistant Secretary of the Air Force (Acquisition) and Yates, Ronald W., Lt Gen, Principal Military Deputy Assistant Secretary (Acquisition), "Air Force Modernization Requirements," Testimony before the Committee of Armed Services, House of Representatives, March 15, 1990.

If successful, the item is then ready for full-scale development.

An example of this flow is the "single crystal" turbine blade. Researchers discovered that a metal crystal could be "grown" in various shapes if certain temperature and pressure conditions were achieved. This idea was then pursued by jet turbine experts in exploratory development to see if turbine blade materials could be "grown" in the shape of turbine blades since the single crystal blade offered strength characteristics that were superior to standard blades. After achieving success in "growing" the single crystal blade, the new blade was inserted into a test engine to determine if the presupposed superior material characteristics of a turbine blade were obtained. Finally, with success of the single crystal blade in the test engine, the new blade technology was ready for incorporation into existing engines to enhance their performance. Since the design characteristics of operational engines (e.g., maximum turbine inlet temperature) usually don't change after their introduction, this new technology provides a blade that has superior strength characteristics and therefore provides extended engine life for existing engines. In addition, since these single-crystal blades maintain their strength at higher temperatures than ordinary blades, they also became important elements of newly designed higher performance engines. Higher temperature operation means that the engine generates a greater engine thrust-to-weight ratio, i.e., the new, lighter engine generates as much thrust as the current engine.

The manner in which this process is pursued gives one insight into the Air Force philosophy of effecting technology transfer. First, the bulk of the funding for basic research (sometimes just referred to as research) goes to U.S. universities. This leverages the excellent U.S. research base and provides the continuing funding to keep it strong. Over the long run this strong research base ensures a steady flow on new ideas in the exploratory development arena.

In exploratory development (6.2), the work is split between the Air Force labs and industry. The idea here is to begin the involvement of industry in the technology development at the earliest stage and balance that with the necessity of keeping the laboratory scientists and engineers involved and current in the actual research.

Finally, in advanced technology development, most of the work is performed on contract by industry as opposed to government laboratory workers ensuring that the technology application is transferred from the laboratory to industry. Then as new weapon systems are needed, the latest technology has already been transferred to the defense industry and is ready for application.[17]

To provide a balance between the development of the technology (research and exploratory development) and the proof of the technology and transition (advanced technology development), Air Force funding is balanced between these efforts during most years.[18]

As noted earlier, in recent years DoD has spent roughly $9 billion per year on its science and technology programs (research, exploratory development, and advanced technology

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[17] Flynn, Michael, Technical Director, Air Force Science and Technology, Office of the Secretary of the Air Force, Washington, DC. Personal Communication in October 1991. The approach to S&T used by each military department is described in the OTA report, "Holding the Edge: Maintaining the Defense Technology Base," p. 4, and agrees with Mr. Flynn's description.

[18] Rankine, Robert R. Jr, "Vision For Air Force Laboratories," Headquarters Air Force Systems Command, USAF, 12 May 1990. Major General Rankine was the Deputy Chief of Staff for Technology in Systems Command, essentially the director of the Air Force Laboratories, when he delivered this briefing. Historical funding charts indicated the balance between 6.1 plus 6.2 and 6.3ATD.

demonstration)[19] of which the Air Force spends approximately $1.5 billion per year.[20]

This philosophy has been very successful for the Air Force. For example, the U.S. has led the world in jet propulsion (gas turbines) since the mid-forties because of the continuing investment of the Air Force in new materials, designs, and techniques. Figure 1 is an illustration prepared by the propulsion directorate of the USAF Wright Laboratory that indicates how each new generation of jet engine at General Electric started as a "demonstrator" in the Air Force's advanced development program (6.3 ATD). Similar charts are available for other industry builders of gas turbines and shows the vital importance of Air Force S&T leadership in U.S. turbine engine development. For example, the engine core technology was developed in the GE1 demonstrator that was the basis for the GE 1/6 engine. This was the first high bypass turbofan. This development led directly to the TF39 engine for the C-5 aircraft. The commercial derivatives of the TF-39 were the CF6 for the Boeing 747, the Douglas DC-10, and the LM2500 series for marine and industrial turbines. The high thrust CF6 engine derivative led to the CF-6 engine for the Boeing 767 and Air Force 1.[21] Notice also that the technology is applicable to ground-based turbines for power generation and to small turbines like those used in helicopters.

Similarly, the development of composite materials began in the Air Force labs in the

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[19] Welch, John J., Jr, Air Force Assistant Secretary (Acquisition), and Jaquish, John E., Principal Military Deputy Assistant Secretary (Acquisition), "Air Force Research and Development Review, Testimony before the Committee on Armed Services, Subcommittee on Research and Development, United States House of Representatives, March 1991.

[20] Ibid.

[21] Welch, John J., Jr., Assistant Secretary of the Air Force(Acquisition),and Yates, Ronald W., LtGen, Principal Military Deputy Assistant Secretary of the Air Force (Acquisition), Testimony before the committee on Armed Services, House of Representatives, "Air Force Modernization Requirements," 15 March 1990.

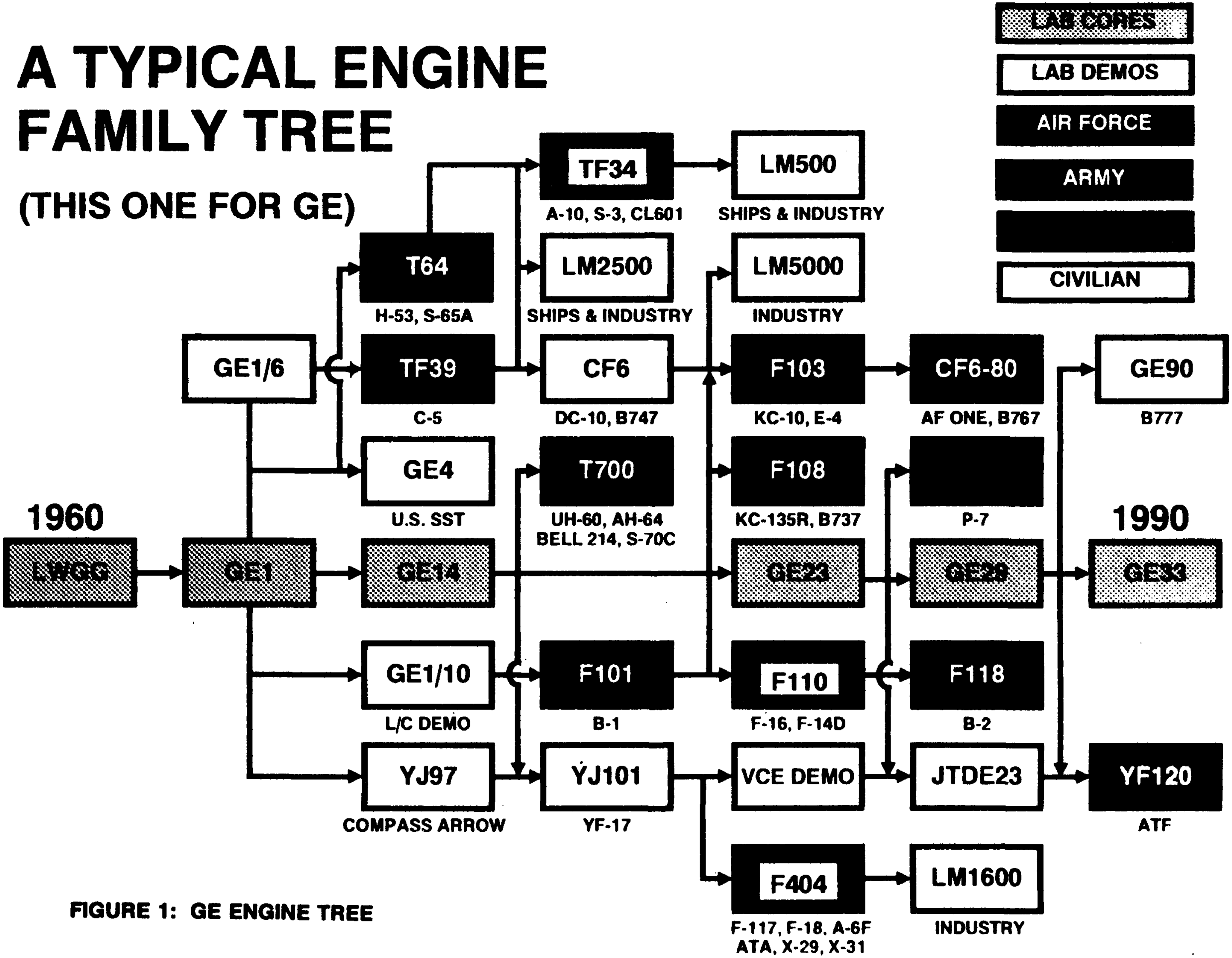

FIGURE 1: GE ENGINE TREE

1950s as Air Force engineers and scientists sought new ways to build light-weight structures. By the 1970s, composite materials were beginning to be incorporated into Air Force aircraft to reduce weight. The F-15 fighter aircraft was one of the first to incorporate these new composites.

This procedure is typical of the introduction of new technology into the aircraft industry in that the military is the risk-taker with enhanced aircraft performance as the goal. Since commercial aviation must be concerned with safety and cost and is therefore more comfortable with proven technology, the Air Force became the leader in the development of composite material technology for aircraft applications.[22] This fact was very apparent to the Japanese who have strongly pushed to get this valuable technology[23].

The F-15 only incorporated about 1% — by weight of aircraft structure — composites, i.e., about 500 pounds of metal was replaced with 215 pounds of composites.[24] This military technology development led to the extensive use of composites by Boeing on its 767 aircraft in the 1980s (10 years after the introduction of composites on the Air Force's F-15 aircraft). Composites were used in many areas of the Boeing 767 resulting in a weight savings of 1238 pounds (4618 pounds of metal was replaced by 3380 pounds of composite materials).

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[22] Ibid.

[23] Prestowitz, Clyde, "Japanese vs. Western Economics: Why Each Side is a Mystery to the Other," *Technology Review,* May\June 1988, p. 33.

[24] Welch, John J., Assistant Secretary of the Air Force (Acquisition), and Yates, Ronald W., Principal Deputy Assistant Secretary of the Air Force (Acquisition), Testimony before the Committee on Armed Services, House of Representatives, "Air Force Modernization Requirements," 15 March 1990.

The Air Force continues to lead in this technology area. Since the new Advanced Technology Fighter will be 40 to 50% composite materials, we can expect that future commercial aircraft will continue to show increases in the percentage of composites in their structure. In addition, "spin-offs" have also occurred in this area with tennis rackets, golf clubs, and even artificial hip joints being made of composite materials.[25]

These two examples demonstrate that the technology transition by the Air Force to defense industries such as Boeing and General Electric have been very effective and in fact have caused these companies to lead the world in the sales of advanced commercial aircraft and gas turbine engines.[26] Indeed, many other examples could be given. In summary, the fact that the U.S. Air Force is the most technologically advanced in the world seems clear evidence that technology transition to defense industries is effective.

TECHNOLOGY TRANSFER LEGISLATION

As international competition began to erode the once commanding U.S. advantage in technology in the 1980s, the Congress began to search for ways to keep commercial industry competitive. One approach was to attempt to better utilize the $70 billion Federal research and development budget. The goal was to facilitate the transfer of the technologies developed in these Federal laboratories to the private sector of the economy as well as state and local governments. In 1980 Congress began work on antitrust and patent retention legislation to

[25] Ibid.

[26] National Science Board, *Science & Engineering Indicators -- 1989.* Washington, DC: U.S. Government Printing Office, 1989, (NSB 89-1), p. 153.

enhance innovation within universities and small businesses. The result is the Stevenson-Wydler Technology Innovation Act of 1980. The Stevenson-Wydler Technology Innovation Act initiated legislation that made it easier for the laboratories to transfer their technologies and provided means of access to laboratory developments. Since then, other initiatives have been included in legislation that modify and improve the original legislation.[27] For example, in 1986 Congress began the effort to speed the technology transfer from Federal laboratories with the Federal Technology Transfer Act. Every year since 1986 has seen additional legislation in this area. Ball[28] provides an excellent summary of this legislation through 1990. In addition, the Federal Laboratory Consortium for Technology Transfer recently published a consolidation of technology innovation legislation.[29]

Table 1 provides a listing of the pertinent legislative acts in this area through 1991. Each of the legislative initiatives are then summarized in the paragraphs following Table 1.

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[27] Hittle, Audie Eugene, "Technology Transfer Through Cooperative Research and Development." Master of Science Thesis. Massachusetts Institute of Technology, June 1991.

[28] Ball, James A., Dilullo, J.G., and Rood, S.A., 1990, "Competition and Economics Spur Technical Initiatives," *Signal,* Vol 44, No 7, March 1990, pp 85-90.

[29] *Technology Innovation,* Chapter 63, United States Code Annotated Title 15, Commerce and Trade, prepared for: The Federal Laboratory Consortium for Technology Transfer, 1991.

Table 1: Technology Innovation Legislation

1.	The Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480).
2.	The Bayh-Dole University and Small Business Patent Procedure Act of 1980 (Public Law 96-517).
3.	Small Business Innovation Development Act of 1982 (Public Law 97-217).
4.	The National Cooperative Research Act of 1984 (Public Law 98-462).
5.	Trademark Clarification Act of 1984 (public Law 98-620).
6.	Japanese Technical Literature Act of 1986 (Public Law 99-382).
7.	The Federal Technology Transfer Act of 1986 (Public Law 99-502).
8.	The National Defense Authorization Act, 1987.
9.	Malcolm Baldrige National Quality Improvement Act of 1987 (Public Law 100-107).
10.	Executive Orders 12591 and 12618 (1987): Facilitating Access to Science and Technology.
11.	The Technology Competitiveness section of the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418).
12.	National Institute of Standards and Technology Authorization Act for FY 1989 (Public Law 100-519).
13.	Water Resources Development Act of 1988 (Public Law 100-676).
14.	The National Competitiveness Technology Transfer Act of 1989 (Public Law 101-189) (included as Section 3131 et seq. of DoD Authorization Act for FY 1990.
15.	National Defense Energy Transfer Act, November 1989.
16.	Defense Authorization Act for FY 1991 (Public Law 101-512).

Each of the legislative initiatives listed in Table 1 are summarized below. Much of this information was taken directly from Hittle and from the new *Technology Innovation* booklet issued by the Federal Laboratory Consortium for Technology Transfer.

1. <u>The Stevenson-Wydler technology innovation act of 1980</u>

   - Established and funded Offices of Research and Technology Applications (ORTAs) at Federal laboratories with 200 or more scientists and engineers, with the purpose of identifying and providing information on technologies to private industry, universities, and state and local governments for use in other research or commercialization efforts.

   -Established the Center for the Utilization of Federal Technology, which is located at the National Technical Information Service.

2. <u>The Bayh-Dole University and Small Business Patent Procedure Act of 1980</u>

   - Allows small firms and universities to get and retain the title to inventions funded by the federal government.

3. <u>Small Business Innovation Development Act of 1982</u>

   - Required agencies to provide special funds for small business R&D connected to the agencies' missions.

4. <u>The National Cooperative Research Act of 1984</u>

   - Permits consortia of companies, with proper registration with the Department of Commerce, to enter into joint ventures without violating antitrust laws (i.e., precompetitive R&D). The low does not allow co-production.

   - Resulted in Consortia: Semiconductor Research Corporation (SEMATECH) and Microelectronics and Computer Technology Corporation (MCC), among others.

5. <u>Trademark Clarification Act of 1984</u>

   - Permitted decisions to be made at the laboratory level in government-owned, contractor-operated (GOCO) laboratories as to the awarding licenses for patents.

6. Japanese Technical Literature Act of 1986

- Improved the availability of Japanese science and engineering literature in the U.S.

7. The Federal Technology Transfer Act of 1986

- Made technology transfer a responsibility of all Federal laboratory scientists and engineers.

- Mandated that technology transfer responsibility be considered in employee performance evaluations.

- Grants government laboratory directors authority to enter into cooperative research and development agreements (CRDAs) with for-profit corporations, to assign patent rights to firms participating in cooperative agreements and to license technologies.

- Provides for the retention of licensing royalties by government labs.

- Mandates that a minimum 15 percent of royalties on Federal patents be awarded to Federal inventors.

- Institutionalized and funded the Federal Laboratory Consortium (FLC) for technology transfer with a charter to transfer technology from the Federal laboratories to industry, universities and state and local governments.

8. The National Defense Authorization Act, 1987

- Encourages the Secretary of Defense to transfer Department of Defense (DoD) developed technology to other U.S. private and public sector organizations and individuals to the extent that it is consistent with national security objectives

- Calls for the Secretary to examine and implement methods to enable DoD personnel to promote technology transfer.

9. Malcolm Baldrige National Quality Improvement Act of 1987

- Established categories and criteria for the Malcolm Baldrige National Industry Award.

10. Executive order 12591 and 12618, "Facilitating Access to Science and Technology," April 1987

- Calls on the Secretary of Defense to promote the commercialization of science and technology; to identify new technologies that potentially would be useful to U.S. industries and universities; and to accelerate efforts to make these technologies more accessible to potential domestic users.

11. The Technology Competitiveness section of The Omnibus Trade and Competitiveness Act of 1988

- Changed the National Bureau of Standards' name to the National Institute of Standards and Technology (NIST) and broadened the organization's role from developing and disseminating measurement standards and scientific data to promoting the commercialization and transfer of Federally developed technology to private industry and state and local government.

- Initiated regional centers for transfer of manufacturing technology, made provisions to assist state technology extension programs, and established a clearing-house for state and local initiatives on productivity, technology, and innovation.

12. National Institute of Standards and Technology Authorization Act for FY 1989

- Reconstituted The National Technical Information Services as the National Technical Information corporation.

- Established a Technology Administration within the Department of Commerce.

- Permitted contractual consideration for rights to intellectual property other than patents in cooperative research and development agreements.

- Included software development contributors eligible for awards.

13. Water Resources Development Act of 1988

- Authorized Army Corps of Engineers laboratories and research centers to enter into cooperative research and development agreements.

14. National Competitiveness Technology Transfer Act of 1989

- Grants contractor-operated Federal laboratories the authority to enter in CRDAs and license technologies to the commercial sector.

- Established time frames to speed up government negotiations for entering into cooperative agreements and exempts cooperative agreements from Freedom of Information(FOI) stipulations for up to five years.

15. National Defense Energy Technology Transfer Act, Amendment to Federal Technology Transfer Act of 1986, Nov 1989

    - Strengthened emphasis and focus on Federal technology transfer from DOE facilities.

16. Defense Authorization Act of FY 1991

    - Established model programs for notional defense laboratories to demonstrate successful relationships between Federal government, state and local governments, and small businesses.

These new laws really have altered the ground rules for the development and dissemination of technology from Federal laboratories including the Air Force Laboratories. For example, patents can now be obtained by a particular company working with a government laboratory and this information can be held as proprietary by the company. Previously this information developed at government expense, even partially, was in the public domain. Government researchers can receive royalty rights and income for inventions developed on the job. A major change!

After an initial period of analyzing the new laws, the Air Force began to actively work toward satisfying the goals of these new Congressional initiatives. In 1988, the Air Force prepared a handbook for "Domestic Technology Transfer" that explained the goals of this new legislation, defined technology transfer, discussed the new responsibilities of Air Force researchers, and described ways of effecting the technology transfer process.[30] The two most

[30] Blair, Douglas E., Air Force Human Resources Laboratory (AFSC) Technology Transfer Handbook: Building our Nation's Strength Through Technology Transfer, U.S. Air Force Human

visible effects of these new laws were the establishment of the Offices of Research and Technology Applications (ORTAs) called for in the Stevenson-Wydler Act of 1980 in each of the Air Force laboratories and the development of Cooperative Research and Development Agreements (CRDAs) called for by the Federal Technology Transition Act of 1986. As a result of the passage of the Stevenson-Wydler Act in 1980, The Air Force created an ORTA in each of its 12 Laboratories. In 1990, the Air Force laboratories were consolidated into four "super" laboratories and ORTAs were also consolidated to provide one office at these new laboratories. These four laboratories are:[31]

- Armstrong Laboratory, Brooks Air Force Base, San Antonio, Texas;
- Phillips Laboratory, Kirtland Air Force Base, Albuquerque, New Mexico;
- Rome Laboratory, Griffiss Air Force Base, New York; and
- Wright Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio.

These offices serve as the initial points of contact for anyone in the state or local government or the private sector and can quickly provide information on the technology of interest and, if required, arrange contact with the scientist or engineer working in the particular technology area. Table 2 is a listing of these ORTAs.[32]

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[31] Welch, John J., Assistant Secretary of the Air Force (Acquisition), and Jaquish, John, LtGen, Principal Deputy Assistant Secretary (Acquisition), "Air Force Research and Development Review," Testimony before the Committee on Armed Services, Subcommittee on Research and Development, United States House of Representatives, March 1991.

[32] Headquarters USAF listing of ORTAs. Provided by Dr. C. J. Chatlynne, Program Manager of USAF Domestic Technology Transfer Program, Office of Assistant Secretary of the Air Force (Acquisition), Directorate for Science and Technology.

Table 2

Air Force Offices of Research and Technology Application (ORTAs)

Armstrong Laboratory AL/XPPO Brooks AFB San Antonio, TX 28235-5601 (512) 536-2796 Doug Blair	Phillips Laboratory Kirtland AFB Albuquerque, NM 87117-6008 (505) 846-0857 Patrick Rodriguez
Rome Laboratory Griffiss AFB Rome, NY 13441-5700 (315) 330-3705 Bill Oaks	Wright Laboratory WL/XPT Wright-Patterson AFB Dayton, Ohio (513) 255-5430 Cindy Ingalls

As mentioned earlier, the second most visible result of the various legislative actions has been the creation of Cooperative Research and Development Agreements (CRDAs) as called out in the Federal Technology Transfer Act of 1986. CRDAs permit government-operated laboratories to enter into agreements with private companies, universities, state and local governments, foundations, not-for-profit organizations, and consortia of such groups. Basically, a CRDA is a written agreement between a Federal Laboratory and a non-Federal organization, which allows each participant to provide personnel, services, facilities, or equipment towards a joint research project. In addition, the outside collaborator, but not the Federal laboratory, can provide funds. The collaborating party may be granted, in advance, an exclusive license to any invention made in whole or in part by a Federal employee, subject to the license to practice or

have the invention practiced throughout the world by or on behalf of the Government.[33]

Some think the biggest advantage of a CRDA its "circumvention of the cumbersome Federal Acquisition Regulation (FAR)."[34] The FAR governs procurement contracts and does not apply to an agreement such as a CRDA.[35] This is by Congressional design to avoid the paperwork and delays inherent in a procurement contract. The Air Force has entered into a number of these Cooperative R&D Agreements beginning in 1988. Tables 3, 4, and 5 list all of the CRDAs recorded at Air Force Headquarters as of January 1992.[36] Table 3 lists the CRDAs for the Laboratories, i.e., Air Force Systems Command. Tables 4 and 5 are included to provide the complete picture of Air Force CRDAs. Tables 4 and 5 also show that although one might expect that the Air Force Laboratories would be the only source of CRDAs, this is clearly not the case. Other Air Force agencies are also using this instrument to effect the transfer of technology.

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[33] Blair, Douglas E., Air Force Human Resources Laboratory (AFSC) Technology Transfer Handbook: Building our Nation's Strength Through Technology Transfer, U.S. Air Force Human Resources Laboratory (AFHRL), Brooks AFB, TX, March 1991.

[34] Department of Defense Domestic Technology Transfer Regulation 3200.12-R-4, The Pentagon, Washington, DC, December 1988.

[35] Hittle, Audie Eugene, "Technology Transfer through Cooperative Research and Development." Master of Science Thesis, Massachusetts Institute of Technology, June 1991, p.34.

[36] Headquarters USAF listing of CRDAs,. Provided by Dr. C.J. Chatlynne, Program Manager of USAF Domestic Technology Transfer Program, Office of Assistant Secretary of the Air Force (Acquisition), Directorate for Science and Technology.

Table 3: Air Force Cooperative R&D Agreements

Systems Command

Date	Title	AF Sponsor	Partner
1988	PC VERSION OF LOWTRAN7	PHILLIPS LAB	ONTAR CORP
1988	KNOWLEDGE-BASED TRAINING SYSTEM	ARMSTRONG LAB	UNIVERSITY OF TEXAS
1989	COMPUTER PROGRAM FOR COMPOSITE MATERIAL ANALYSIS	WRIGHT LAB	ADTECH SYSTEMS RESEARCH, INC
1989	MODIFICATION OF MOPAC 5.0 SOFTWARE TO PREDICT CHARACTERISTICS OF CHEMICAL COMPOUNDS	AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (SEILER RESEARCH LAB)	EASTMAN KODAK
1989	EVALUATION OF DATATREE FOR DATA COMPRESSION	PHILLIPS LAB	IBM
1989	SEMIEMPIRICAL COMPUTATIONAL METHODS	AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (SEILER RESEARCH LAB)	OXFORD CONTINUING EDUCATION PROGRAM
1990	SYNTHESIS OF AROMATIC BENZOXAZOLE POLYMERS	WRIGHT LAB	DAYCHEM LABORATORIES
1990	MOPAC FOR HIGH PERFORMANCE VAX AND RISC SYSTEMS	AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (SEILER RESEARCH LAB	DIGITAL EQUIPMENT CORPORATION
1990	GL GLOVAL SPECTRAL MODEL	PHILLIPS LAB	ATMOSPHERIC AND ENVIRONMENTAL RES
1990	PHOTONICALLY FED, SMALL-SCALE PHASED ARRAY ANTENNA	ROME LAB	GENERAL ELECTRIC
1990	NEUTRAL PARTICLE BEAM TEST STAND	PHILLIPS LAB	SCIENCE APPLICATIONS INTERNATIONAL
1990	STRENGTH PROPERTIES OF CONCRETE	AIR FORCE CIVIL ENGINEERING SUPPORT AGENCY	SOUTHWEST RESEARCH INSTITUTE
1990	MANUFACTURE AND TESTING OF INDIUM PHOSPHIDE CHIPS	ROME LAB	KOPIN CORPORATION
1991	TEST AND EVALUATION OF SELF ELECTRO-OPTIC EFFECT DEVICES	ROME LAB	AT&T BELL LABS
1991	FURTHER EXPLORATION OF COMPRESSION/DECOMPRESSION COMPUTER ALGORITHMS FOR COMMERCIALIZATION	PHILLIPS LAB	IBM
1991	IMPROVE USEFULNESS OF GLOBAL POSITIONING UNIT/INERTIAL NAVIGATION SYSTEM	PHILLIPS LAB	ROCKWELL INTERNATIONAL
1991	MECHANICAL PROPERTIES HANDBOOKS	WRIGHT LAB	PURDUE UNIVERSITY
1991	TRANSFER INTELLIGENT TUTORING TECHNOLOGY TO INDUSTRY	ARMSTRONG LAB	UNIVERSITY OF TEXAS LEHIGH UNIVERSITY SAGE ED SYSTEMS

Table 4: Air Force Cooperative Agreements
Air Force Academy

Date	Title	AF Sponsor	Partner
1990	HYPERSONICS TEXTBOOK	AIR FORCE ACADEMY	AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS
1990	VIDEODISK TECHNOLOGY FOR FOREIGN LANGUAGE EDUCATION	AIR FORCE ACADEMY	NATIONAL EDUCATION FOUNDATION
1991	LANGUAGE LEARNING CENTER	AIR FORCE ACADEMY	ACADEMY RESEARCH AND DEVELOPMENT INSTITUTE
1991	IDENTIFICATION OF ILLEGAL INTERNATIONAL DRUG SHIPMENTS	AIR FORCE ACADEMY	McDONNELL DOUGLAS ELECTRONIC SYSTEMS
1991	NATIONAL AEROSPACE PLANE WIND TUNNEL TESTING	AIR FORCE ACADEMY	KOHLMAN AVIATION

Table 5: Air Force Cooperative R&D Agreements
Surgeon General

Date	Title	AF Sponsor	Partner
1989	SYNTHETIC GORETEX GRAFT	MEDICAL CENTER KEESLER AFB	W.L. GORE & ASSOC.
1989	MARINE MUSSEL DERIVED BIOADHESIVES	WILFORD HALL MEDICAL CENTER	BIOPOLYMERS, INC
1990	BURN WOUND TREATMENT	MEDICAL CENTER KEESLER AFB	CHAI-TECH CORP

CRDAs are viewed by many as a promising means for transferring technology from the Government labs to industry.[37] In fact, some have called for an expansion of the CRDA idea to the full R&D arena.[38] A number of S&T agreements have been made, as evidenced by the Tables 3, 4, and 5. And, according to a telephone interview with the ORTA at Armstrong Lab, Mr. Doug Blair, he expects that there will be many r~~e added in the near future.[39] Thus the Air Force has made a good start. There are still problems to overcome, however. Mr. Blair makes the point that the infrastructure for this technology transfer is not fully in place. The Air Force has its ORTAs in place and is actively educating its scientists, engineers, and technology managers concerning the importance of technology transfer and means of effecting it. The major problem now is to let the user (private companies, state and local governments, universities, etc.) know what is available and how to go about obtaining it. The links between the user and the Air Force ORTAs must be made and institutionalized, i.e., a technology transfer infrastructure built. This is now underway and Mr. Blair and the other ORTAs are making contact with various companies, universities, state and local governments,and consortia. Hittle makes the same point

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[37] Hittle, Audie Eugene, "Technology Transfer Through Cooperative Research and Development." Master of Science Thesis. Massachusetts Institute of Technology, June 1991, p. 31.

[38] Bingaman, Jeff, Gansler, Jacques, and Kupperman, Robert, "Integrating Commercial and Military Technologies for National Strength: An Agenda for Change. " Report of the CSIS Steering Committee on Security and Technology, The Center for Strategic & International Studies, Washington, DC, 1990, p. xvii.

[39] Blair, Douglas E., Office of Research and Technology Assistance, Armstrong Laboratory, Systems Command, Brooks AFB, TX. Personal Communication.

and calls for the initiation of a major awareness campaign by the Air Force.[40] He stresses that the government-industry CRDAs need to be clearly distinguished from the Federal acquisition system to dispel the perception of government red tape.

A note of caution must be mentioned about CRDAs. As they become more numerous, their inherent shortcomings will have to be confronted. For example, since they were purposely placed outside of the Federal Acquisition Regulations, the safeguards in these regulations do not apply. For example, researchers are not bound by the competition-in-contracting act (CICA), and thus can select the contractor of their choice for the agreement. It seems obvious that this arrangement could lead to an agreement with a company that favors the researcher's interests over those of the government.

IS AIR FORCE DOMESTIC TECHNOLOGY TRANSFER EFFECTIVE?

From the foregoing discussion, it is clear that prior to 1980 this question was much easier to answer simply because technology transfer to the non-defense commercial sector was not really a consideration. Although desirable, the transfer of defense laboratory technology was primarily aimed at defense industries. Today that is no longer true. Because of Congressional initiatives (laws) in the 1980s, this question now must also include the transfer of technology to all domestic entities. Consequently, it's perhaps easier to attempt an answer if time is divided into two periods; (1) prior to 1980, and (2) from 1980 to 1991.

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[40] Hittle, Audie Eugene, "Technology Transfer through Cooperative Research and Development.: Master of Science Thesis, Massachusetts Institute of Technology, June 1991, p. 2.

Prior to 1980

As mentioned earlier, prior to 1980, the major emphasis for technology transfer was from the Air Force Laboratories to the defense industry. There are numerous examples of successes of USAF technology transfer during this period and two major success stories were given earlier. Could the technology transfer been more efficient? Almost certainly. But the transfer was successful, and the fact that the U.S. Air Force was more capable (technologically superior) to all other Air Forces in the world is really the best argument for effectiveness.

1980 to 1991

During this period, technology transition to the defense industry continued to be effective. The military laboratories continued their technological leadership and the flow of technologies from the laboratory to the defense industry continued to provide superior weapon systems. Interestingly, the laboratories also began to take advantage of "spin-in", i.e., using commercially developed technologies for military application. In summary, the Desert Storm operation of 1991 clearly demonstrated the technological superiority of the U.S. Air Force and should be ample proof of the effectiveness of this continuing technology transition.

Technology transfer to the other domestic entities (nondefense industry, state and local government, etc) began in ernest during the late 1980s. Progress has been made as evidenced by the establishment of Offices of Research and Technology Assistance at each Air Force Laboratory and the negotiation and signing of numerous Cooperative Research and Development Agreements (CRDA). Based on these points, the effort must be rated as effective. However, some measure of effectiveness needs to be established in the future to allow managers to gage

their efforts. Should that be the number of CRDAs? The royalty value of the CRDAs? Or some other measure? This measure should be carefully thought out as it will tend to drive the entire program in the future. Without some clearly stated objective, the goal will probably become the total number of CRDAs without any regard to the usefulness of the individual CRDA. Ultimately this could become an obstacle to quality CRDAs and reduce the effectiveness of the desired domestic technology transfer.

FUTURE USAF DOMESTIC TECHNOLOGY TRANSFER

The Air Force Laboratories are now faced with two goals in technology transfer. The first goal is the historic one, to ensure that the U.S. Air Force is the superior air force in the world by keeping its technology superior. This requires development and transference of technology to the defense industries. The second goal is the one mandated by Congress beginning in 1980 to transfer technologies to the private sector to enhance the U.S.'s competitiveness.

The difficulty is that these goals are conflicting. Military superiority, the first goal, allows the researcher to focus on developing technologies that enhance the mission capability of the operator or "war fighter." Any advantages that the commercial sector receives are merely "spin-offs" and are not the primary goal of the technology transfer process. In fact, a collateral objective is to limit the transfer of technology outside the defense industries to prevent this technology from falling into the hands of the enemies of the U.S. Military technologies that have a commercial value or "dual-use" technologies have always been a dual-edged sword. The Defense Department has always been concerned with technologies that offered military advantage that also had a commercial value. If these technologies are released to the commercial sector

where they are freely available to anyone, they can easily flow to the military establishment of a potential enemy.

On the other hand, domestic technology transfer's goal is to maximize the transfer of technology to domestic entities. In an environment of economic competition, this becomes an important element of national security. But should the Department of Defense be directed to carry out an essentially commercial program that conflicts with the basic goal of military research? Indeed, the government laboratory researcher, when faced with a choice, may be persuaded to pursue "commercially useful" technologies in lieu of "militarily useful" technologies simply because development of the commercially useful technology may be financially rewarding personally, i.e., royalties.

It appears that one solution to this dilemma would be to create a civilian agency that has the mission of developing technologies that are necessary for the U.S.'s economic security. This agency would be a part of a cabinet level department (Department of Commerce?) and would direct laboratories that develop commercial technologies for economic strength just as the DoD laboratories were created to develop technologies that are necessary for the U.S.'s national defense. The national laboratories would be a part of this new agency. The military laboratories could continue to transfer technology when appropriate and would be coordinated with this new government agency and its "commerce laboratories." However, the major emphasis for the development and transition of technologies to the commercial sector would be the responsibility of this new agency.

In summary, the Air Force has been effective in developing and transferring technologies to weapon systems through defense industries throughout its history. Since 1980 and the onset

of various laws conceived to speed the transfer of technologies to the commercial sector, the Air Force has also been effective in responding to these new laws and building an infrastructure to effect the desired transfer. ORTAs have been established and are working to build relationships that will enhance technology transfer to the U.S.'s commercial entities.

Leaders in Congress and the Executive branch of government must take care, however, to ensure that the fundamental mission of the Air Force laboratories not be distorted because of panic about the nation's competitive economic position.

The fundamental mission of the Air Force laboratories must always be the development of technologies needed to ensure a superior United States Air Force!